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How a Tree Grows

LEAVES of trees and other plants are the most important chemical factories in the world. Without the sugar plants make and the energy plants store, there would be little food for humans or animals; no wood to build our homes or make furniture, tools, paper, and thousands of other products for vital human needs; no coal, petroleum, or natural gas to heat our homes, offices, and factories, or to power our cars, trucks, planes, and trains; and no humus to enrich the soil. (Oil and much natural gas comes from deposits of tiny sea plants and animals.)

Without the oxygen that plants produce, there could be no animal life, including human.

Sunlight, air, water, and soil are the basic elements trees need to live and grow.

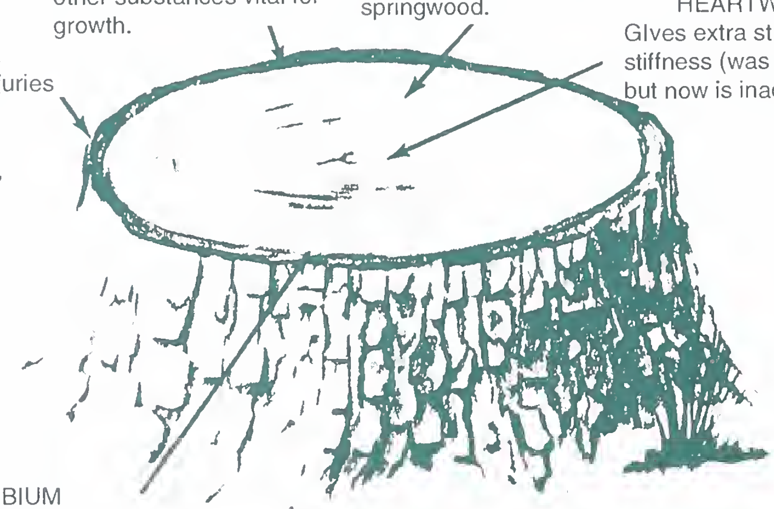
Sunlight provides the energy for the leaf "factories." In the leaves, water from the roots combines with **carbon dioxide** from the air to form simple sugars like **glucose.** This process is carried on inside each leaf by millions of green-colored, microscopic **chloroplasts.** Taken together, these tiny bodies are called **chlorophyll**; they give leaves their worldwide green color.

Oxygen is a byproduct of this process—and is released into the air. This is how humans and other animals get the oxygen they must have to breathe and exist. And the animals exhale carbon dioxide, which plants need just as badly, into the air where trees and other plants pick it up. Thus we see that plants and animals are completely dependent upon each other.

This fundamental manufacturing process is called **photosynthesis** (from "photo" meaning "light" and "synthesis" meaning "to put together").

THREE GROWING PARTS

Trees have three main growing parts—the **root tips**; the **stem tips**; and the **cambium layer**, which is found between the bark and the wood throughout the tree. The growing points of the stems develop into branches, leaves, and flowers; the flowers become fruits or nuts, maturing into seeds. The cambium layer, only a single cell in width, divides into **xylem,** or **sapwood,** on the inside, and **phloem,** or **bark,** on the outside.



Trees increase each year in height and spread of branches by adding a new growth of twigs from young cells in the buds at the ends of the twigs.

The sapwood carries water and dissolved minerals (sap) up from the roots to the leaves, through a network of microscopic **vessels**. As the tree grows older, the sapwood becomes heartwood, the center core of the wood, which is often darker in color. The wood gives the tree its strength and upright form, and furnishes people with countless thousands of essential and useful products. Most of the useful wood is in the **trunk**, which supports the leafy **crown**.

The inner bark has a special function, which we will see in a moment. The outer bark, which gets thick and scaly with age, protects the tree from injuries of all kinds.

What happens to the all-important sugar made in the leaves?

It is carried by a network of tiny "pipes" (sieve tubes) in the inner bark to all living cells in the tree. Every living cell—from root tips to crown tips—goes to work on the sugar, with the aid of special **enzymes**, to make it into new products.

Enzymes start or speed up certain chemical reactions. Each enzyme does a special job, working with split-second timing and in harmony with the others. In general, the enzymes break down sugar and recombine it with the **nitrogen** and **minerals** that are dissolved in the water carried up from the root tips.

TREES MAKE FOODS

In this second manufacturing stage, some sugar is changed to other foods, some is made into new cells as the tree grows, and some is made into various special substances. Some sugar is used directly to provide the energy for growth in the buds, cambium layer, and root tips. People tap hard maple trees for their sugary sap to make maple syrup and maple sugar.

Other foods made by the tree are **starches, fats, oils,** and **proteins**—all of which help to form flowers, fruits, nuts, and seeds, and may also be stored in the roots and wood during the dormant season. Seeds are sometimes dropped in great profusion, and help assure reproduction of the tree and the forest.

The new cells produced in this second process are principally the new wood and bark. The cell walls of the wood consist mainly of **cellulose fibers** and **lignin**. The cell walls of the bark are mainly cellulose and **suberin**. Lignin is a dark-colored chemical substance that seeps into the wood fibers and gives them extra hardness and strength. Suberin is a waxy, fatty substance that seeps into the looser, corky fibers of the bark and thus protects the living cells in the cambium area from drying out and dying, which would cause the death of the tree.

Some of the special substances made in the tree that have uses in industry are: rosin and turpentine from southern pines; chewing gum from chicle trees and spruces; tannin for leather-making from hemlocks, oaks, and chestnuts; vanillin for ice cream; birch beer; sassafras tea; chemicals used to make resins, plastics, rayon, photo film, etc.

It is curious that only a tiny fraction of the water absorbed by the tree roots is required for the chemical process of photosynthesis—less than 1 percent. The remaining 99 percent plus is transpired ("breathed" out as water vapor along with air) through the tiny openings, stomata, mostly on the underside of the leaves. However, this transpiration serves as an important function. It helps to maintain the uniform cool temperature in the leaves that is needed for photosynthesis.

THE TREE AND THE SOIL

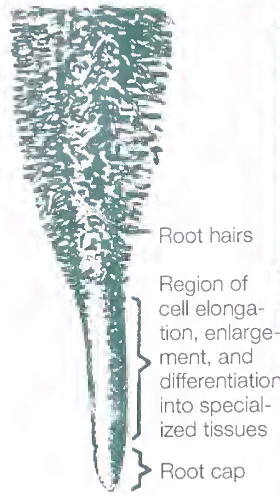
There is a very close relationship between trees and the soils they grow in. The soil is the storage place for water, and the nitrogen and minerals dissolved in water, which are needed by the tree to live and grow. The soil also provides a base for the tree to attach itself firmly in place. The roots, reaching out for water, between the soil particles, serve to anchor the tree as well.

Forest soils and the trees growing on them support a great variety of plants and animals, ranging from big game like elk, moose, and bear to life of microscopic size.

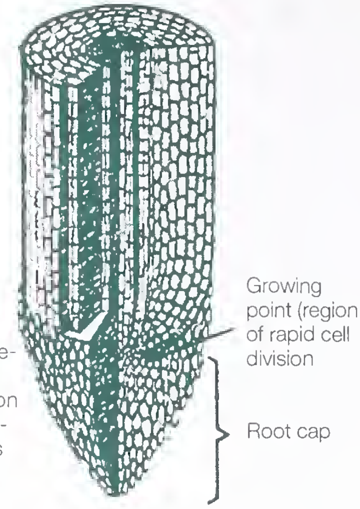
What kinds and how much of such life there is depend on the type of soil, and the kinds of trees and other shrubs growing there—all of which are greatly affected by climate and rainfall. All these elements are closely interrelated, and together they make up what is called the **ecosystem** or community.

Soils vary considerably in fertility, texture, color, depth, acidity, ability to hold water, and in many other ways, depending on (1) the type of rocks from which the soils were formed; (2) the climate (hot or cold, wet or dry); (3) the trees, bushes, and other plants growing in the soils; (4) the animal and bird life of the areas; (5) whether the soils weathered in place from the bedrock, or were moved to the places they now rest by ice (glaciation), water (streamflow), gravity (sliding), or wind; (6) slope of the land; (7) age, and other factors.

The growing root tips, very small but very numerous, each covered with a protective cap of cells, push into the soil to extend the many-branching root system *(see enlarged sketches, top right)*. Just behind each tip is a dense fuzz of microscopic root hairs growing out all around the rootlet. It is these tiny root hairs that absorb the gallons and gallons of water and dissolved minerals that the tree needs each day during the growing season to live and grow. As the rootlet becomes longer and larger, the older hairs die and are sloughed off, new ones grow closer to the growing tip.



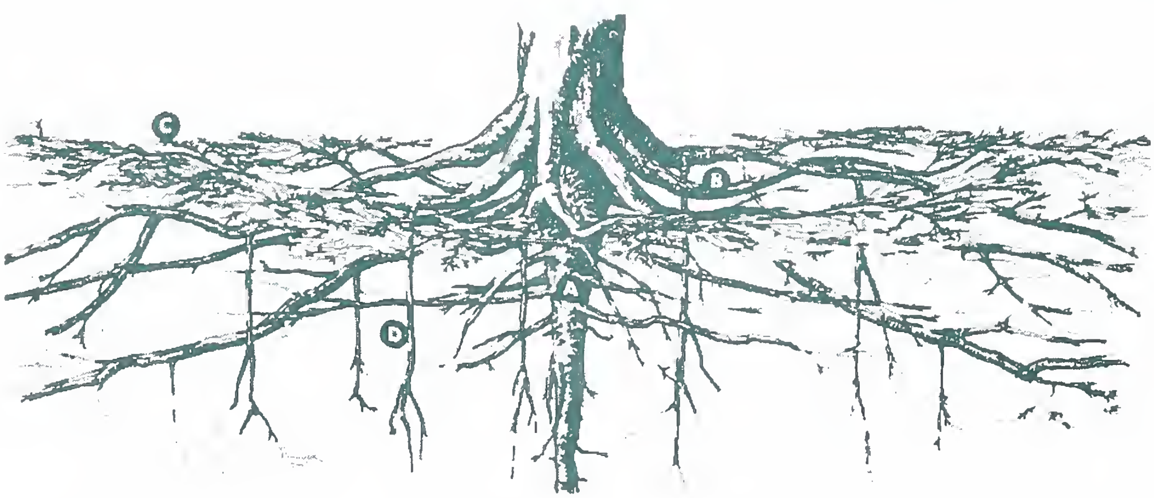
Enlarged view of the end of the root.



Root tip greatly magnified.

ROOT SYSTEM

The root system sketched below is growing in a soil that has no rooting restrictions, such as shallow bedrock, or dense, compact clay layers. Note the big taproot and the many smaller lateral roots extending far out on each side—all of which give strong support to the tree and anchor it firmly in place. (Of course, many



Tap Root (A)—Provides main support of tree and anchors it firmly in the ground. (Not all trees have one.)
Lateral Roots (B)—Help support and anchor trunk, may extend far out, beyond crown spread.
Fibrous Roots (C)—Masses of fine feeding roots close to ground surface.
Deeply Descending Roots ("Sinkers") (D)—Grow downward from lateral roots.

species of trees do not have taproots.) A few roots descend deeply into the soil from the lateral roots.

Some roots may extend down into the soil very deeply—often 12 feet and sometimes 30 feet or more. Lateral roots may extend from the trunk for long distances also—often 35 feet in each direction and sometimes much more. But most feeding roots are usually in the top 2 or 3 feet of soil. The kind of tree, its age, type of soil, moisture available, competing vegetation, and other factors determine the extent of the root system.

In a typical forest of the temperate zone, where the climate is neither extremely cold or hot most of the year nor excessively dry, the soil near the surface is loose, soft, easily crumbled, and usually moist. This natural mellowness is protected and maintained by a covering of fallen leaves, fruits, nuts, twigs, branches, and trunks in various stages of decay—which is called **litter** or **mulch.** This fall of litter averages over a ton per acre per year in the United States, and is often much more where growth is heavy. It also includes material from animals—feathers, fur, feces, and carcasses of insects, birds, mice, squirrels, etc.

LITTER AND HUMUS

The litter in **coniferous** forests (where evergreens such as pines, hemlocks, cedars, spruces, and firs grow) is often deeper, taking longer to decompose into **humus**, than the litter in **broad-leaved** forests. Oaks, hickories, ashes, maples, birches, beeches, walnuts, and poplars are broad-leaved trees, which are **deciduous** (drop their leaves in the fall).

The layer of litter or mulch conserves soil moisture by slowing down evaporation into the air. The litter also protects the surface soil from erosion by absorbing raindrops as they fall. (When raindrops fall on bare soil, they break down the small crumbly lumps of soil into tiny particles. These particles quickly wash away into streams or close the pores in the soil, compacting it.) A bare soil more readily allows runoff of rainwater, thus leading to gullies and floods. This happens after forest fires and careless logging.

A loose, porous surface soil ("A" layer) is important to good plant growth, since it allows air and water to penetrate to where most of the roots are. The surface soil of the typical broad-leaved forest is often fairly dark in color, enriched with the decomposed **organic matter** (humus) from the litter, and dead roots.

LIFE OF THE SOIL

The litter and surface soil is the home of many ants, beetles, grubs and other insects, spiders, mites, springtails, millipedes, snakes, worms, and small rodents (such as mice and shrews). All these little creatures mix the litter with the soil, and their burrows let rainwater and melting snow drain more quickly into the subsoil.

The surface soil is also teeming with myriad microscopic life—**bacteria** and **fungi** —which decompose the dead plant material (leaves, twigs, and roots), dead animals, insects, etc., making it all part of the soil. Important nutrients are thereby added to the soil. This organic matter is eventually broken down to the basic substances —such as carbon dioxide, water, minerals, and nitrogen—used by trees and other plants.

A light sandy soil supporting evergreen trees has fewer soil organisms than a loamy soil on which broad-leaved trees often grow.

EACH SOIL HAS A PROFILE

Each soil develops distinct layers (horizons). The layers of a soil form the **soil profile**. The profile is distinctive for each soil type. Forest soils are usually undisturbed as compared with farm soils that are plowed frequently, so forest soils retain their natural profiles better.

The separate layers of a soil differ from one another in various physical and chemical characteristics. They vary in color, amount of organic (dead plant and animal) material, size and proportions of soil particles, acidity, and in amount of plant nutrients present.

Soil particles are classified as **clay, silt,** and **sand**, in order of increasing size. Coarse fragments of rocks such as gravel and stones are frequently present.

The soil layers are partially formed by the downward and sideward percolation of water through the soil. This water carries with it certain dissolved materials, such as lime and very fine clay particles. The water also moves organic matter, iron compounds, and other materials from the surface layer to lower layers. The movement of the soluble materials in the soil by water is called **leaching.**

"A," "B," AND "C" HORIZONS

The surface layers, which are known as the "**A**" horizons, are often thoroughly leached, and may or may not be dark-colored. The layer immediately underneath, the "**B**" horizon, is the zone where the accumulation of clay particles and certain mineral compounds is greatest.

Below the "**B**" horizon, is the "**C**" horizon, where the soil material has changed relatively little by the soil-forming process. Sometimes it is material that has weathered from the underlying bedrock, but it may also have been transported to its present location by water (rivers and streams), wind, ice, or gravity. The "**C**" horizon often becomes coarser and more stony with depth as it approaches bedrock.

Because forest soils in the United States vary so greatly, we cannot describe one, or even a few soils, as being typical of **all** forest soils. But we can describe actual examples of important forest soils. The next page contains two such examples.

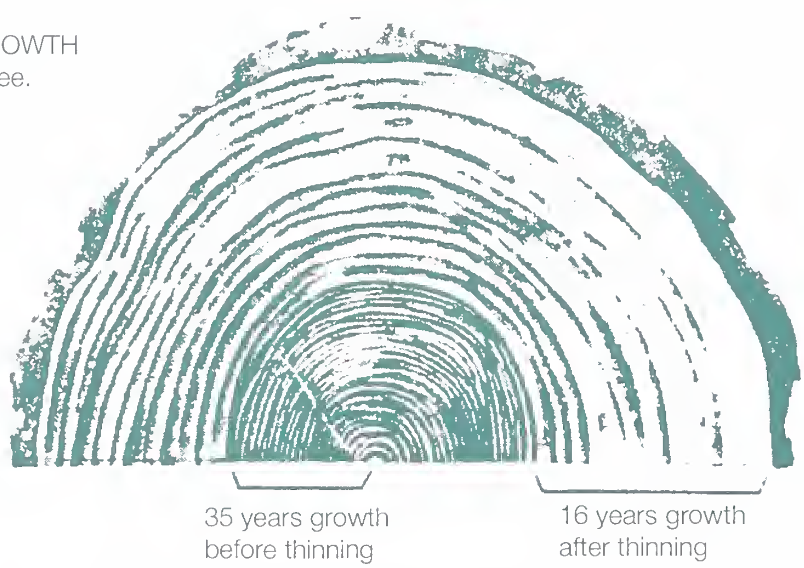
CONCLUSION

Whether living in the backwoods or in a crowded city, regardless of occupation, people are concerned with the welfare of the forests. They may be inclined to take most things for granted—the newspaper, the easy chair, the water that flows from the kitchen faucet—without stopping to think that they come from the forest. Forests provide the raw materials for countless products needed for modern living.

Most American homes are built of wood; all have some wood in their construction. Furniture, books, magazines, baseball bats, turpentine for paints, and rosin for soaps are products of the forests, as are rayon, sausage casings, and photographic film.

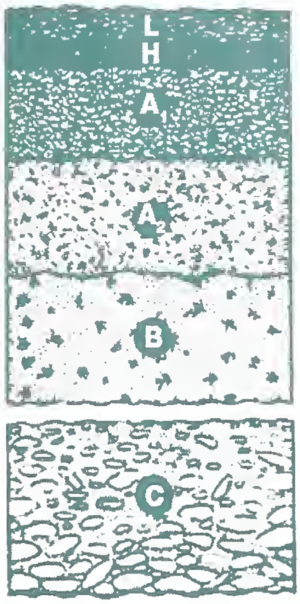
Forests will always be necessary to both the economic and social life of this country, so we must make sure that they are kept productive. Nothing can replace them as sources of industrial wealth, as conservators of water and soil, as recreation grounds, and as the home of wildlife and game. To maintain enough forest growth for the demands now made upon them and the greater demands of the future, our forests must be managed wisely, and our depleted forest lands must be restored to productivity.

THINNING INCREASES GROWTH
Annual rings show age of tree.



SOIL NO. 1—NORTHEAST

This is a soil of the humid, temperate, hill-and-mountain region fro western Virginia northward to Pennsylvania. Forests of oaks, hickories, and yellow poplars grow on this soil. The decayed leaves and twigs in the **H** (humus) layer are mixed with mineral soil in the **A_1** layer by earthworms and other soil animals. When this soil was found on flat or gently sloping lands, it was often cleared and plowed, and became good farm soil. The mineral soil developed from weathering of the underlying **dolomite** (a type of limestone that contains magnesium as well as calcium carbonate.)



L — This leaf litter, 1- to 2-inches deep
H — This, dark-colored humus layer, 1/2 to 1 inch

A_1 — Surface mineral soil, a medium textured silt loam, granular, dark-colored, about 4-inches thick, moderately acidic

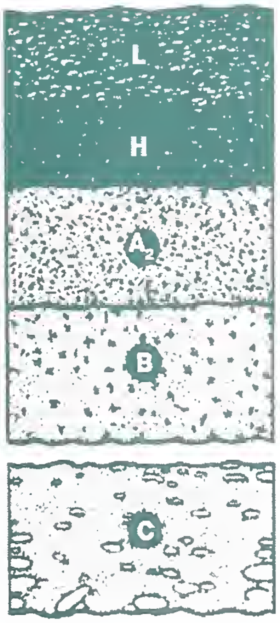
A_2 — Leached subsurface horizon, medium textured silt loam, may be platy (made up of flaky layers) instead of granular, grayish-brown, about 6-inches thick, strongly acidic

B—Subsoil horizon, moderately fine (silty clay loam), blocky structure, brownish color, 18- to 36-inches thick, strongly acidic, enriched from above with clay particles and iron, aluminum, or other compounds

C—Substratum or parent material—amount of rock fragments increases with depth and gradually becomes bedrock (limestone or slates), medium texture, up to several feet thick, yellowish brown.

SOIL NO. 2—GREAT LAKES REGION

This is sandy soil of northern forests in Wisconsin and adjacent areas. The terrain is flat. The trees are balsam fir, northern white cedar, basswood, and yellow birch—a mixture of evergreen and broad-leaved species. In this soil, the **H** (humus) layer does not mix with the mineral soil, so there is no A_1 horizon. When this soil was cleared, the farms were not naturally very productive. The mineral soil developed from glacial till (a mixed deposit of sand, clay, gravel, and boulder left by a glacier during the last Ice Age).



L—Moderately thick leaf litter, 3- to 4-inches deep, dark brown to black

H—Moderately thick humus layer of fibrous organic material, about 3 inches thick, dark brown

A_2—Sandy leached surface horizon, about 5-inches thick, grayish-brown, moderately acidic

B—Sandy subsoil horizon, enriched with iron compounds, brown in color, about 24-inches thick, moderately acidic

C—Sand substratum horizon, several feet thick, brown in color. Water table (ground water level) covers up part of this layer, coming up to within 3 to 4 feet from the surface of the ground.

(This publication combines and supersedes D-4, How a Tree Grows, and D-8, The Tree and The Soil.)

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